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GEOGRAPHIC INFORMATION SYSTEM — A COMPUTER ASSISTED APPROACH TO MANAGING FOREST PEST DATA

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GEOGRAPHIC INFORMATION SYSTEM - A COMPUTER ASSISTED APPROACH TO MANAGING FOREST PEST DATA

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ABSTRACT

Use of the USDI Fish and Wildlife Service, Geographic Information System - MOSS to store, analyze and display spatial data of interest to Forest Pest Management is described. A nine theme data base was constructed for gypsy moth, Lymantria dispar L., infestations in Mifflin County, Pennsylvania. Using MOSS, statistical data, and maps depicting gypsy moth status and trend were prepared. The system was also used to measure net area of spray blocks, establish buffer zones along sensitive streams in spray blocks, and evaluate foliage protection following treatment.

Data entry, analysis and map production was performed at a cost of approximately seven cents per acre.

INTRODUCTION

Much of the data required in resource management is spatial in nature (Berry 1981). Locations of areas with a common attribute (i.e., vegetation type, landform, resource use) are represented as points, lines, polygons or grid cells on maps. Through a systematic overlay of individual data themes such as location of timber stands, critical wildlife habitat, or mineral deposits, areas of potential resource conflict can be identified and the consequences of alternative management strategies on each resource system can be identified.

Management of forest pests is no exception. Areas of potential pest hazard or actual pest damage are characteristically identified as polygons of land area with a common attribute; similar levels of hazard or damage. These can be interfaced with other resource data themes as an initial step in estimating pest impacts or identifying areas of potential conflict. For example, location of pest activity can be overlaid over prime timber or recreation sites to identify those areas where timber or recreation impacts might be expected. Similarly, areas proposed for treatment can be overlaid on locations of environmentally sensitive areas (streams, lakes, areas of human habitation) to identify sites of potential conflict.

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Today most spatial resource data are stored on maps, map overlays or microfiche facsimiles. Storage of these products is often cumbersome and retrieval is inefficient. In addition, maps may become damaged or lost. Analysis of spatial data stored in this manner is tedious and time consuming. Resultant data are often not available for timely decision making.

In recent years a number of computer based Geographic Information Systems (GIS) have become available. These systems provide the capability to store, analyze and retrieve spatial data in a computer. Individual data themes can be accessed, combined with other data themes and analyzed providing timely information to support decisionmaking.

There has been considerable interest by Forest Pest Management in the use of GIS technology to store, retrieve, display, and analyze forest pest status data and interface it with other resource data. Recent demonstrations of this technology have either been published or are in press (Young, 1977, 1979; Daniels et al. in press). This paper describes some of the capabilities of a public domain GIS; Map Overlay and Statistical System (MOSS) developed by USDI, Fish and Wildlife Service Western Energy and Land Use Team and its uses in forest pest management.

SYSTEM CHARACTERISTICS

MOSS is a display and analysis spatial information system used by the Fish and Wildlife Service and other agencies for processing geographic data. The Service began developing MOSS in 1975 as a tool for analyzing the voluminous information resulting from increased resource development activities in the West and the impending threat posed to wildlife populations. Service personnel realized that computers were being underutilized as a tool in natural resource management, particularly for evaluating spatial map data. MOSS has since evolved into a user-oriented information system capable of performing numerous map manipulations ranging from simplistic map data display to advanced cartographic modeling. System design was controlled by the needs of the users; resource agencies, for applications which have included but are not limited to land use planning, regional energy development, impact analysis, Environmental Impact Statement preparation, wildlife habitat assessment and forest planning.

MOSS is a command-driven system currently operating on a Data General C-350 Eclipse minicomputer at the U.S. Fish and Wildlife Service's Western Energy and Land Use Team (WELUT) in Fort Collins, Colorado. MOSS is user friendly and can be accessed in batch or demand mode via a graphics terminal. Each MOSS command represents a capability that can be used to process map data. These commands are executed by typing in the name of the command followed by any options or parameters associated with the command. For example, to determine the interaction between a soil type map and a timber stand map the command OVERLAY is executed. A combined map is created which can be stored for further map manipulations. Maximum utilization of a GIS is achieved when the data is used repeatedly (deSteiguer and Giles 1981). Once the map data is stored in MOSS, the user is able to display and analyze the cartographic

information using over 100 commands available to best evaluate the specific resource application.

MOSS can analyze data in both polygon and grid cell (raster) format. The cellular processing capability expands the range of data availability to include LANDSAT imagery and elevation or terrain models.

Three subsystems are contained in MOSS; data entry, data analysis, and map preparation. The data entry subsystem is known as Analytical Mapping System (AMS). This subsystem copies data by tracing original map data with an electronic digitizer which impulses XY coordinates into the computer. MOSS (also the name of the overall GIS) is the subsystem that performs all data and display functions. The Cartographic Output System (COS) uses original or derivative MOSS data to produce high quality map products (Fig. 1-6).

DATA BASE CONSTRUCTION

A nine theme multi-resource data base was constructed for Mifflin County, Pennsylvania to demonstrate the capabilities of MOSS to retrieve and analyze data of direct interest to Forest Pest Management. This data base was constructed using the computer facilities of WELUT in Fort Collins, Colorado. Mifflin County was selected because it was part of a 1981 test site for evaluation of high altitude panoramic aerial photography for mapping defoliation by gypsy moth, Lymantria dispar L. (Ciesla and Acciavatti 1982), and was the only county that occurred in the test site in its entirety.

Data themes were digitized from the 18 USGS 7 1/2 minute topographic maps which make up Mifflin County. Themes, corresponding codes, and definition are as follows:

1. Mifflin County Boundary (CNT) - The Mifflin County line was digitized as a separate data theme directly from the topographic map base.

2. Forested Areas (FOR) - Areas printed in green on the USGS topographic map base were defined as forested areas. All other areas were defined as non forest.

3. Landownership Class (OWN) - State forest, State park, and private lands were classified and digitized as a single data theme. Each polygon was identified by ownership (i.e., Tuscarora State Forest, Rothrock State Forest, Reeds Gap State Park, etc.).

4. Roads (RDS) - Major roads and highways were digitized into a single data theme.

5. 1981 Spray Blocks (BLK) - Location of each block treated for control of gypsy moth in 1981 was digitized. Blocks were identified by block number as designated by the Pennsylvania Bureau of Forestry.

6. Major Streams (STR) - All rivers and perennial streams were digitized.

7. Towns (TWN) - Boundaries of all major communities were digitized.

8. 1981 Defoliation (DEF) - Moderate (Class 4) and Heavy (Class 6) defoliation as mapped by high altitude panoramic aerial photography in 1981 (Ciesla and Acciavatti 1982) was used as the source for this data theme. A data holiday occurred in the western third of the county because of improper flight line spacing during the aerial photo mission.

9. 1982 Defoliation (D82) - Moderate and heavy defoliation as mapped by aerial sketchmap surveys conducted by the Pennsylvania Bureau of Forestry was used for the 1982 defoliation data theme.

Each data theme was stored by individual 7 1/2 minute quadrangle map and coded by theme and map name. For example, the map of 1981 defoliation on the Burnham Quadrangle was designated DEFBURNHM. Similarly the map of spray blocks on the Allensville Quadrangle is BLKALLENS. Presently 162 individual maps comprise this data base.

Using MOSS, analyses were conducted to obtain estimates of annual defoliation by landownership class, estimates of cumulative defoliation, net area of spray blocks, identification of sensitive areas in spray blocks, and comparison of defoliation in and around spray blocks.

FOREST PEST MANAGEMENT APPLICATIONS

Current Pest Status - Tabular data on areas defoliated can be obtained for an individual quadrangle or any combination of merged quadrangles simply by executing the AREA command for any of the DEF or D82 maps (Table 1).

Area of defoliation by landownership class is obtained by an overlay of the 1981 or 1982 defoliation maps (DEF or D82) maps with their corresponding ownership (OWN) maps. Again, these commands can be executed for individual quadrangles or any combination of merged maps in the data base, including the entire county (Tables 2 and 3).

A high quality map showing current years defoliation can be produced with COS. Defoliation can be displayed relative to any or all of the themes which exist in the data base. Map scale, color, shading and lettering options are user driven commands. COS can produce a stand alone paper map product or a mylar overlay that can be used in combination with a USGS topographic map or planimetric county highway map (Figures 1-3).

Cumulative Defoliation - Effects of tree defoliation such as growth reduction or tree mortality are generally a function of years of successive defoliation as well as defoliation intensity. These data are especially difficult to derive and become increasingly difficult as the annual records in the historical data file increase. With a GIS, area of cumulative defoliation for 2+ years are derived from overlays of annual defoliation maps. In the Mifflin County data base a summary of areas defoliated for two successive years is derived from an overlay of the 1981 defoliation maps (DEF) with the 1982 defoliation maps (D82) (Table 4).

Table 1 - MOSS PRINTOUT OF AREA SUMMARIES OF 1981 AND 1982 HARDWOOD DEFOLIATION, LEWISTON QUADRANGLE - MIFFLIN COUNTY, PENNSYLVANIA

1981

SUBJECT	AREA	FREQUENCY	PERCENT
CLASS 4 (Moderate Defol.)	4588.87	27	87.90
CLASS 6 (Heavy Defol.)	631.95	19	12.10
TOTAL (in acres)	5220.8	46	100.00

1982

SUBJECT	AREA	FREQUENCY	PERCENT
CLASS 4 (Moderate Defol.)	2551.01	9	51.75
CLASS 6 (Heavy Defol.)	2378.41	8	48.25
TOTAL (in acres)	4929.4	17	100.00

Table 2 - AREA SUMMARY OF 1981 AND 1982 HARDWOOD DEFOLIATION BY LANDOWNERSHIP CLASS, LEWISTON QUADRANGLE - MIFFLIN COUNTY, PENNSYLVANIA

Landownership Class	Defoliation Class: Moderate	Heavy	Total
	1981		
Tuscarora State Forest	1107	343	1451
Private	3480	288	3768
Total	4587	631	5219
	1982		
Tuscarora State Forest	2333	1046	3379
Private	218	1333	1551
Total	2551	2379	4930

Table 3 - AREA SUMMARY OF 1981 AND 1982 HARDWOOD DEFOLIATION BY LANDOWNERSHIP CLASS, MIFFLIN COUNTY, PENNSYLVANIA

Landownership Class	Defoliation Class		
	Moderate	Heavy	Total
	-1981-		
Private	18474	8327	26801
Bald Eagle State Forest	2549	1569	4118
Rothrock State Forest	699	6162	6861
Tuscarora State Forest	4329	1086	5415
Reeds Gap State Park	1	0	1
Total	26052	17144	43196
	-1982-		
Private	8360	7996	16356
Bald Eagle State Forest	1513	280	1793
Rothrock State Forest	98	6	104
Tuscarora State Forest	677	9752	10429
Reeds Gap State Park	0	0	0
Total	10648	18034	28682

Table 4 - AREAS OF HARDWOOD FOREST DEFOLIATED IN 1981 AND 1982 MIFFLIN COUNTY, PENNSYLVANIA

Defoliation Class		Acres
1981	1982	
Moderate	Moderate	2387
Moderate	Heavy	4384
Heavy	Moderate	553
Heavy	Heavy	358
Total		7682

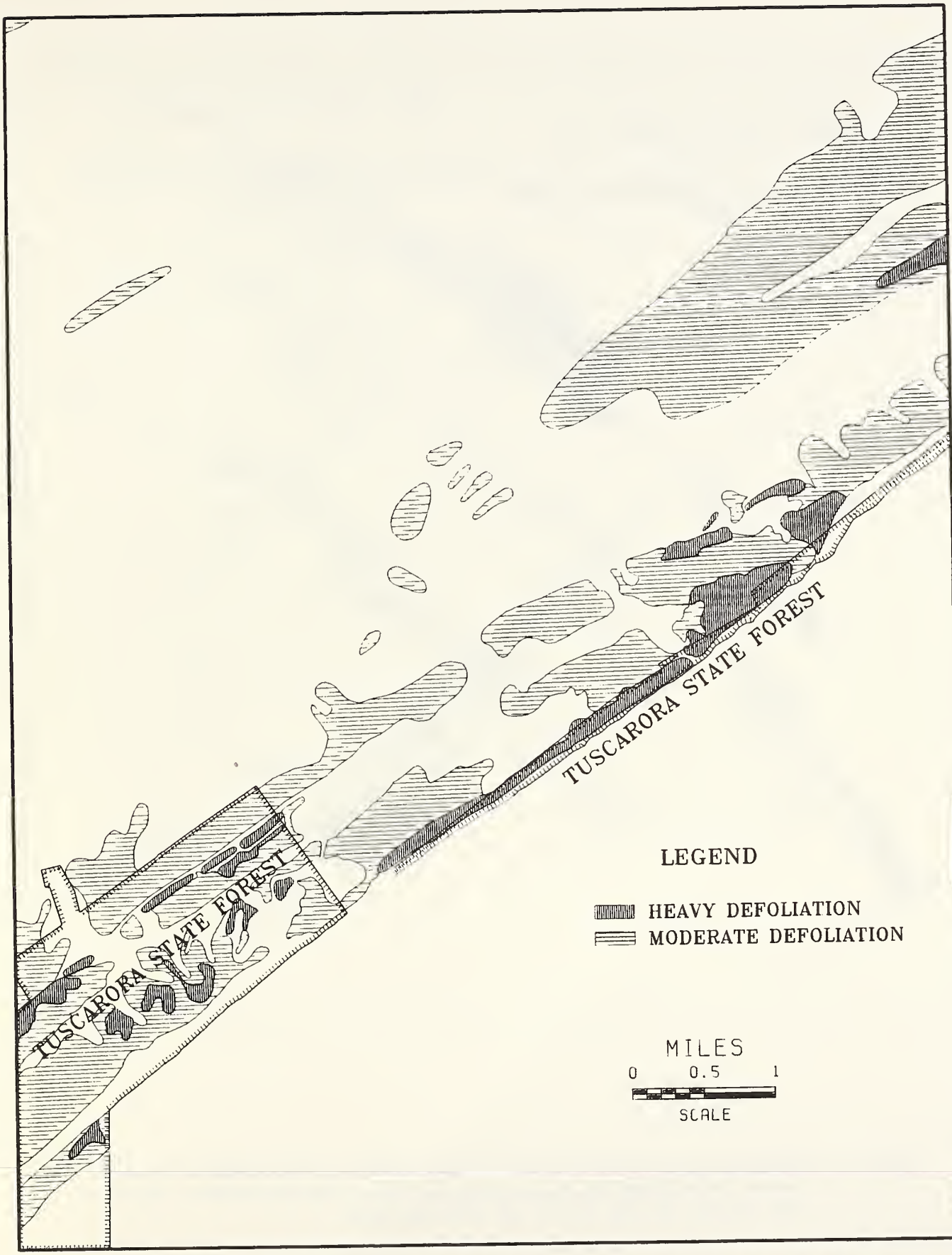

Figure 1 - Computer generated map of the Lewistown Quadrangle, Mifflin County, Pennsylvania showing 1981 gypsy moth defoliation relative to State Forest lands.

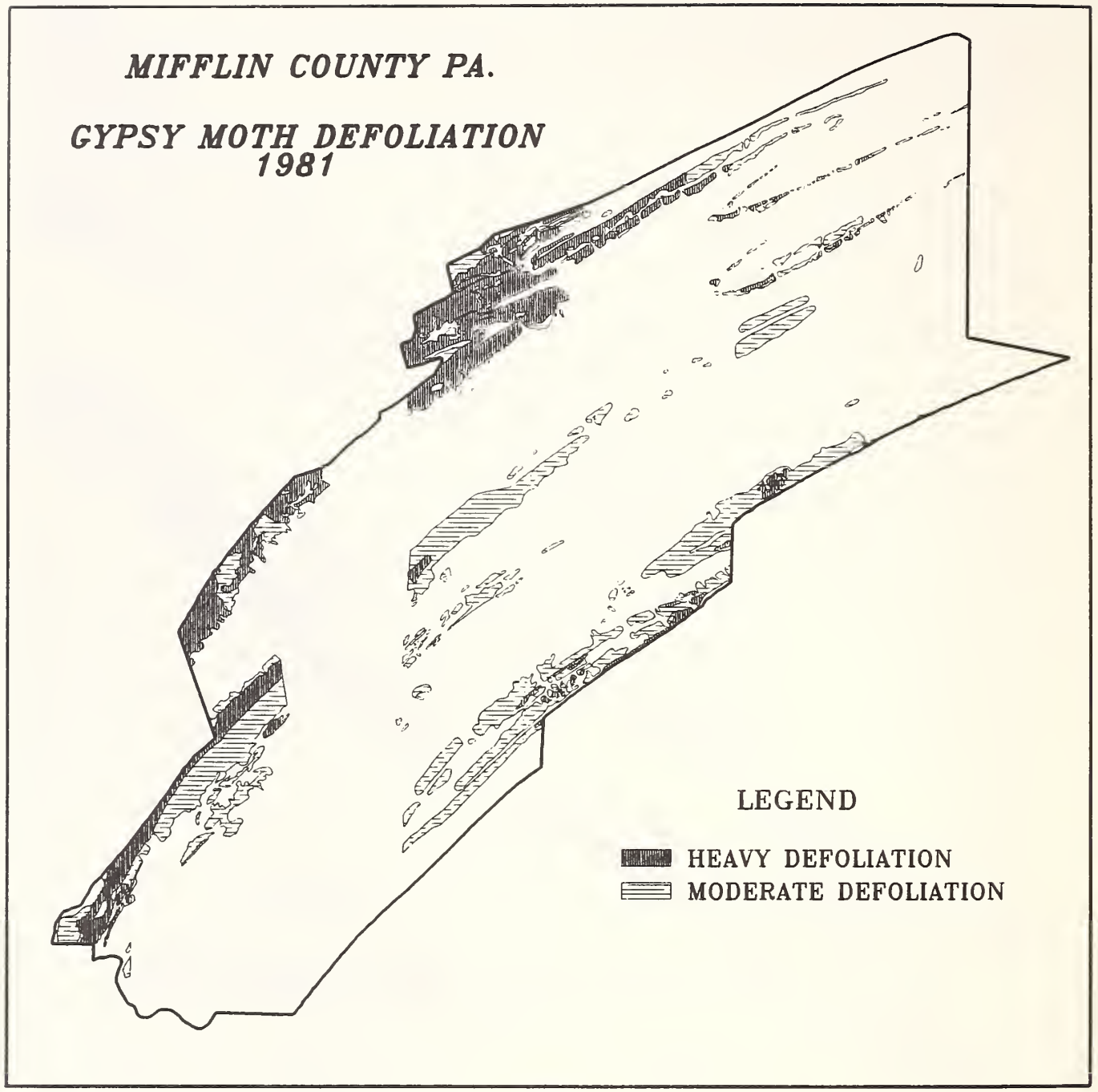

Figure 2 - Computer generated map of Mifflin County, Pennsylvania showing areas defoliated by gypsy moth in 1981. Gap in western third of the county is the result of missing data.

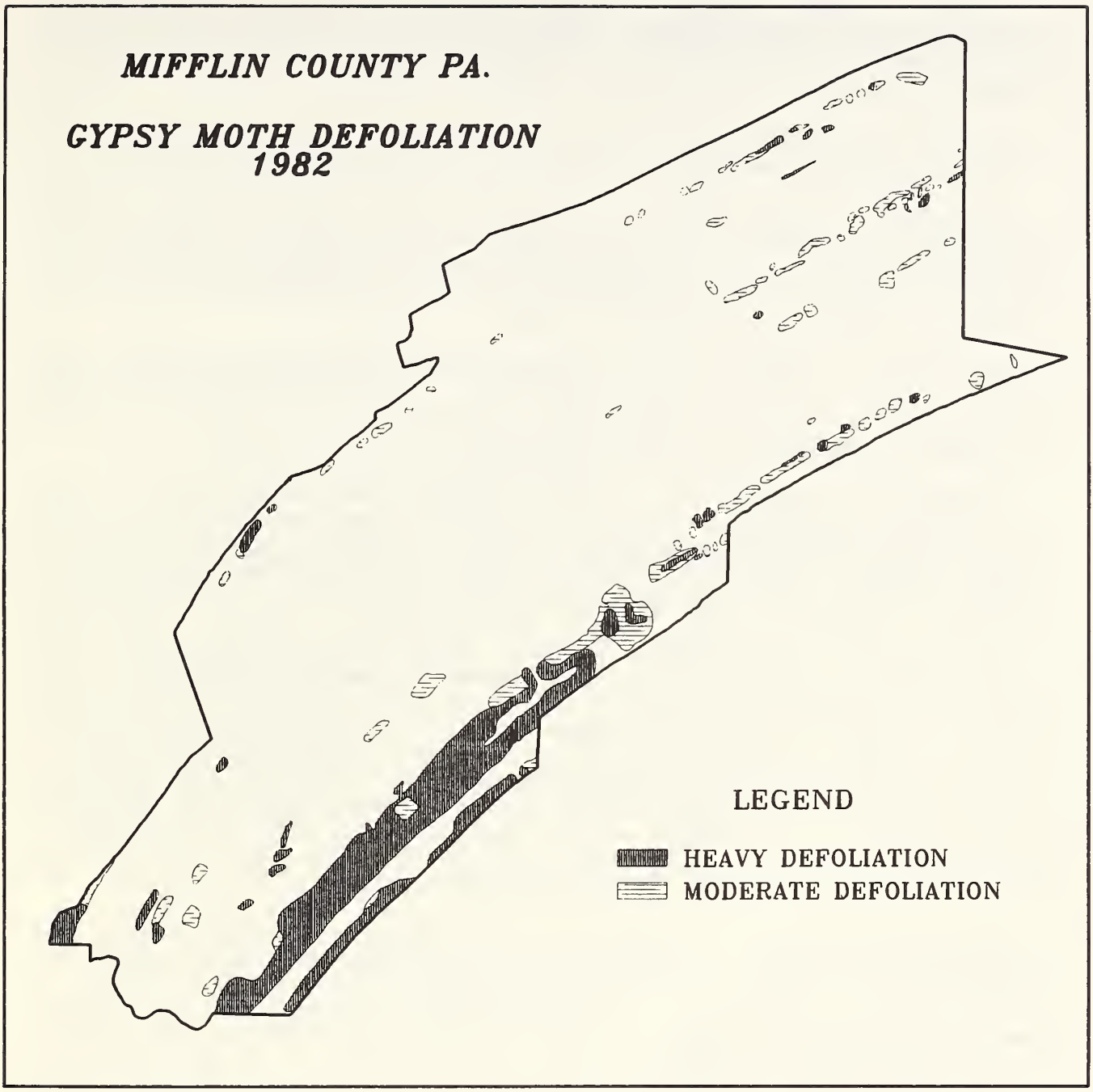

Figure 3 - Computer generated map of Mifflin County, Pennsylvania showing areas defoliated by gypsy moth in 1982.

A more detailed breakdown by landownership class can be obtained from subsequent overlay of the DEF/D82 maps and their corresponding ownership (OWN) maps (Table 5). Summaries of areas defoliated only in 1981 or 1982 can be obtained in a similar manner (Tables 6 and 7).

A COS map showing areas defoliated in 1981 only, 1981 plus 1982 and 1982 only can be produced using the various shading options available (Figure 4).

Suppression Project Planning and Evaluation - Existence of a spatial data base provides a number of opportunities for planning and evaluation of suppression projects. This includes determination of gross and net area of proposed treatment areas, establishing buffer zones around sensitive areas and evaluation of foliage protection.

Gross area of spray blocks is readily obtained by executing the AREA command for the spray block data theme (BLK). Net area, or area of forest cover, within each spray is obtained by an overlay of the BLK maps and the forest-non forest data theme (FOR) (Table 8).

Comparisons of estimates of net area obtained from a MOSS BLK/FOR overlay vary considerably with area estimates provided by the Pennsylvania Bureau of Forestry with Pennsylvania Bureau of Forestry estimates being considerably higher (Table 8). This is attributed to the fact that the FOR data theme was obtained entirely from USGS topographic maps. Net area of spray blocks is initially obtained by the Pennsylvania Bureau of Forestry from USGS topographic maps. These data are modified and updated by District, County and Area personnel from ground data and occasionally, aerial photographs. This generally increases the net area of individual spray blocks by 5 to 15% over what is measured from the topographic maps.[4/] Examination of spray blocks on high altitude panoramic aerial photographs shows considerably more area of forest cover than do the USGS topographic maps. This discrepancy is amplified in area proposed for treatment because many of these areas are partially wooded residential areas which are not shown as forest cover on the USGS map base. Other discrepancies are attributed to errors inherent in map transfer and area computation in both GIS and conventional methods.

In suppression project planning it is frequently necessary to buffer sensitive areas such as streams or lakes. The GIS data base allows for establishment of buffer zones through a series of interactive BUFFER and overlay commands with the BLK and streams (STR) or roads (RDS) data themes. When the overlays are completed, area of buffer can be subtracted from the original spray block acreage.

For example, Strodes Run flows through spray blocks 19, 20, and 21. A 100 foot buffer zone was established either side of the stream. Area of the buffer was subtracted from the gross area of each spray block (Tables 9, 10, and 11). Buffered areas can be displayed graphically if desired (Figure 5).

[4/]Personal communication; John Quimby and William Slippey, Pennsylvania Bureau of Forestry, Harrisburg, PA.

Table 5 - AREAS OF HARDWOOD FOREST DEFOLIATED IN 1981 AND 1982 BY LANDOWNERSHIP CLASS, MIFFLIN COUNTY, PENNSYLVANIA

Landownership Class	Acres of Hardwood Defoliation (1981/1982)[1]				
	Mod/Mod	Mod/Heavy	Heavy/Mod	Heavy/Heavy	Total
Private	1859	2134	314	187	4494
Bald Eagle State Forest	382	60	107	3	552
Rothrock State Forest	0	4	65	2	71
Tuscarora State Forest	146	2185	67	167	2565
Total	2387	4383	553	359	7682

[1] Rounded to nearest acre.

Table 6 - AREAS OF HARDWOOD FOREST DEFOLIATED IN 1981 AND NOT IN 1982 MIFFLIN COUNTY, PENNSYLVANIA

Landownership Class	Acres of Moderate and Heavy Defoliation
Private	21,818
Bald Eagle State Forest	3,566
Rothrock State Forest	6,760
Tuscarora State Forest	2,850
Total	34,994

Table 7 - AREAS OF HARDWOOD FORESTS DEFOLIATED IN 1982 AND NOT IN 1981 MIFFLIN COUNTY, PENNSYLVANIA

Landownership Class	Acres of Moderate and Heavy Defoliation
Private	11,858
Bald Eagle State Forest	960
Rothrock State Forest	32
Tuscarora State Forest	7,862
Bald Eagle State Park	3
Total	20,715

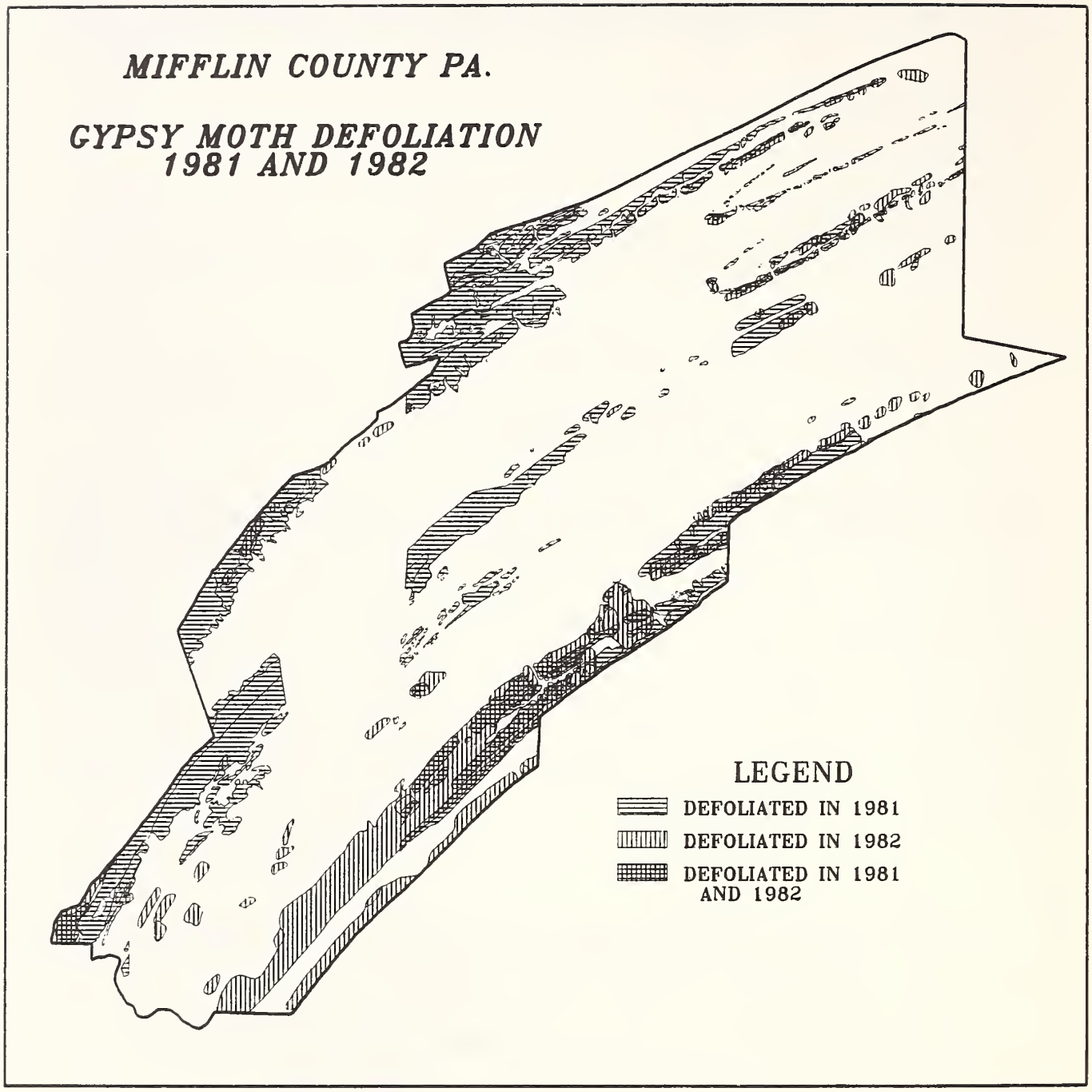

Figure 4 - Computer generated map of Mifflin County, Pennsylvania showing areas defoliated by gypsy moth in 1981 and 1982.

Table 8 - GROSS AND NET AREAS OF 1981 SPRAY BLOCKS, MIFFLIN COUNTY, PENNSYLVANIA

Block No.[1]	Gross Area (MOSS BLK) (Acres)	Net Area (MOSS BLK/FOR (Acres)	Net Area (PA BUREAU FORESTRY)	% DIFF[2]
1	129.51	74.02	105	29.5
2	72.00	49.42	51	3.1
3	26.70	.92	24	96.2
4	60.86	44.18	48	7.95
5	6.15	6.08	6	-1.33
6	11.44	3.57	9	60.33
8	46.00	40.86	45	9.2
9	111.96	69.03	81	14.77
10	24.58	18.75	27	30.55
11	34.55	54.54	57	4.32
13	51.33	30.51	48	36.43
14	68.45	53.56	60	10.73
17	60.28	26.95	36	25.14
18	70.93	31.33	42	25.40
19	81.43	67.32	72	6.50
20	47.22	34.25	39	12.18
21	64.47	48.08	54	10.96
23	33.63	22.91	30	23.63
24	166.18	104.40	150	30.4
25	215.50	184.67	201	8.12
26	191.19	102.16	135	24.32
27	7.57	4.02	6	33.00
28	28.39	26.12	33	20.85
29	32.40	12.68	21	39.62
30	29.96	13.76	27	49.04
31	183.49	105.97	144	26.04
32	117.78	98.22	96	-2.31
33	79.61	45.33	72	37.04
34	49.58	40.09	48	16.47
35	57.46	40.58	60	32.37
36	105.62	66.67	84	20.63
37	76.48	19.13	66	71.02
38	63.41	25.13	45	44.15
39	175.45	33.67	90	62.59
40	23.24	18.10	21	13.81
41	129.82	97.44	117	16.72
42	16.80	11.85	21	43.57
43	67.04	57.44	63	8.82
44	82.40	67.27	78	13.76
45	248.27	248.24	264	5.97
Total	3168.74	2099.62	2676	21.5

[1] Blocks 7, 12, 15, 16 and 22 were not included in the data base because they fell within the area where 1981 defoliation data was not available.

[2] $\frac{\text{PA NET - MOSS NET}}{\text{PA NET}} \times 100$

Table 9 - MOSS PRINTOUT OF GROSS AREA SUMMARY FOR GYPSY MOTH SPRAY BLOCKS 19, 20, AND 21, MIFFLIN COUNTY, PENNSYLVANIA 1981

Block	Area	Frequency	Percent
MIFF - 19	81.43	1	42.17
MIFF - 20	47.22	1	24.45
MIFF - 21	64.47	1	33.39
Total (in acres)	193.1	3	100.00

Table 10 - MOSS PRINTOUT OF AREA OF BUFFER ADJACENT TO STRODES RUN FOR GYPSY MOTH SPRAY BLOCKS 19, 20, AND 21, MIFFLIN COUNTY, PENNSYLVANIA 1981

Block	Area	Frequency	Percent
MIFF - 19	5.09	1	23.07
MIFF - 20	12.02	1	54.49
MIFF - 21	4.95	1	22.44
Total (in acres)	22.1	3	100.00

Table 11 - NET AREA OF GYPSY MOTH SPRAY BLOCKS 19, 20, AND 21 FOLLOWING REMOVAL OF BUFFER ZONES, MIFFLIN COUNTY, PENNSYLVANIA 1981

Block	Area
MIFF - 19	73.64
MIFF - 20	35.20
MIFF - 21	59.52
Total (in acres)	168.4

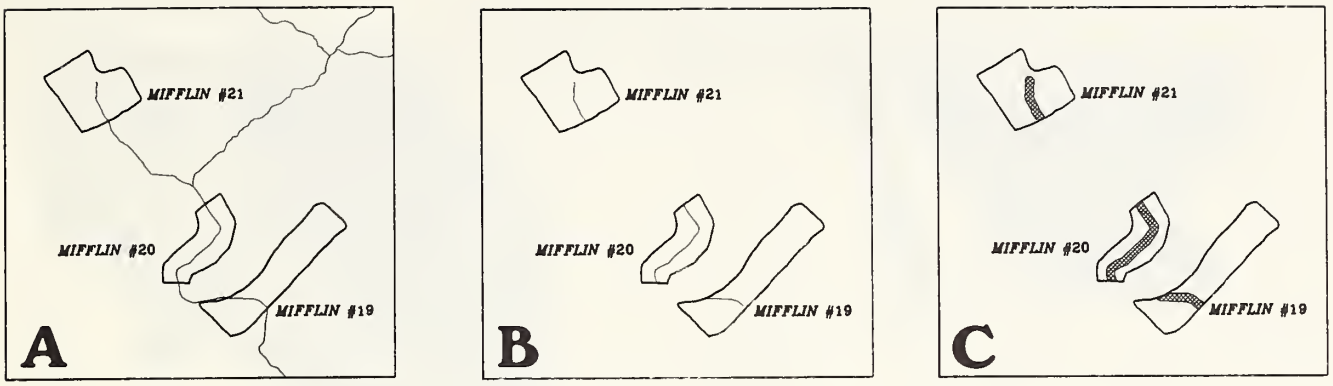

Figure 5 - Use of MOSS to buffer a sensitive stream within a spray block. A - The data themes STR and BLK are superimposed on a Graphics CRT. B - Using the command LPOVER portions of stream segment occurring within each spray block are identified. C - A 100 foot buffer zone is created using the command BUFFER, the area of the buffer zone is obtained with the command AREA and is subtracted from the original area of each spray block (See Tables 9, 10 and 11).

Evaluation of foliage protection is done by comparison of defoliation in the spray block with surrounding untreated areas of the same or similar cover type and pest population density (Ciesla, 1983). This can be done on a graphics terminal by superimposing the BLK over the DEF data themes for each USGS map (Figure 6). Area of defoliation is obtained for each spray block from a BLK/DEF overlay (Table 12).

TIME AND COSTS

The data entry process is the most time consuming step in building a geographic data base. Time required to digitize a data theme is directly proportional to the quality and complexity of the data. Times required for entry of individual data themes used in the development of this data base ranged from nine to 96 person hours (Table 13). Less than 200 person hours were required to provide the data analysis and map products required by this evaluation.

Data base construction and subsequent analysis cost approximately $15,000 or $.067 per acre. This cost was achieved by using U.S. Fish and Wildlife Service computer hardware and software already in place. In addition, personnel experienced with MOSS were used for data entry and analysis. Initial cost of creating a data base of this type would increase considerably if hardware had to be purchased or the MOSS software was converted to another computer system.

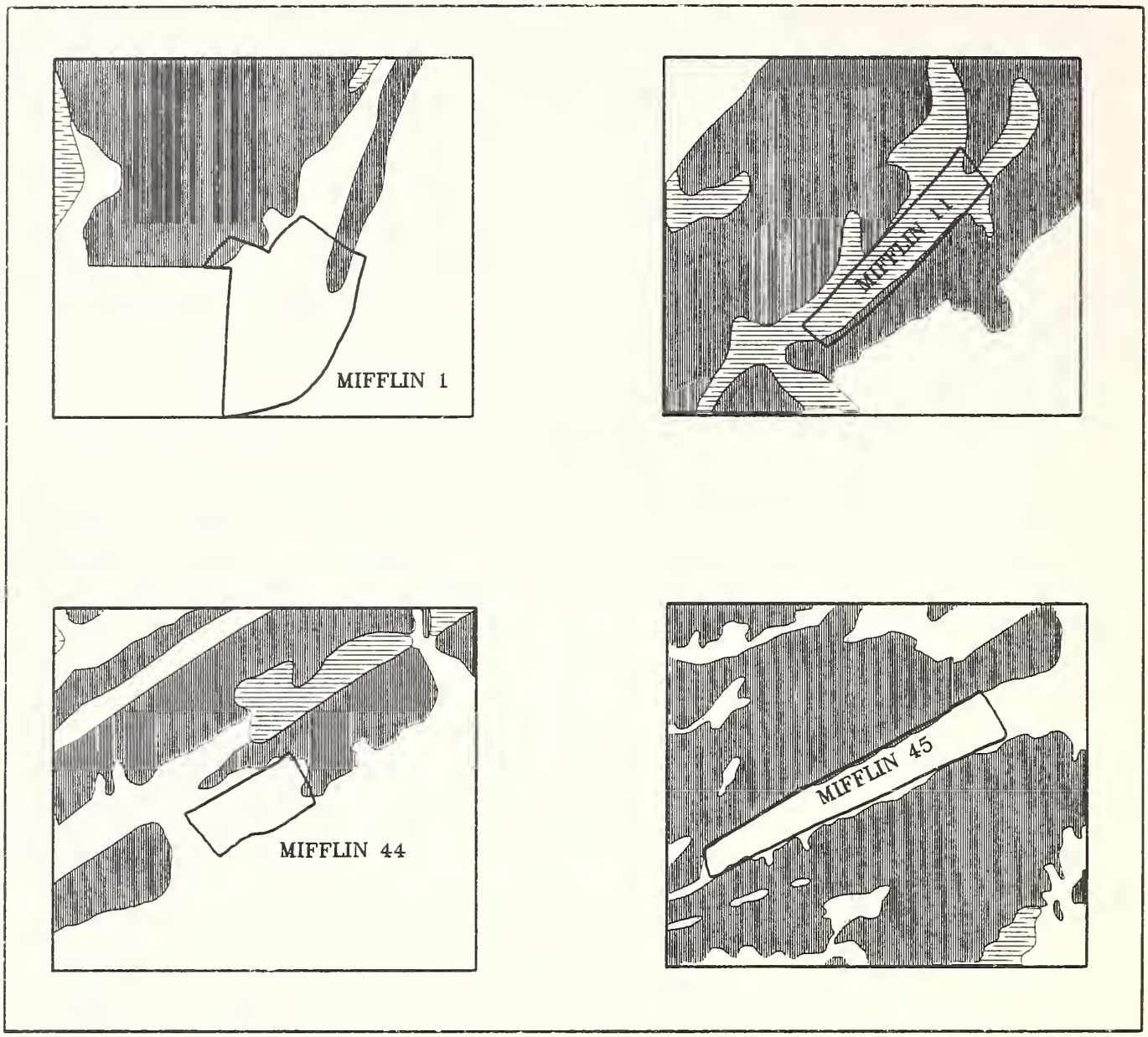

Figure 6 - Computer generated maps created by superimposing the data theme DEF (1981 defoliation) over BLK (1981 spray blocks). These maps show degree of foliage protection achieved from application of aerial sprays directed against gypsy moth larvae.

Table 12 - AREA OF HARDWOOD DEFOLIATION IN BLOCKS TREATED FOR CONTROL OF GYPSY MOTH, MIFFLIN COUNTY, PENNSYLVANIA 1981

Block #	Total Area (Acres)	Net Area (Acres)	Area Defoliated (Acres) Moderate	Heavy	Total
1	129.51	74.05	0	9.8	9.8
2	72.00	49.42	0	0	0
3	26.70	.92	0	0	0
4	60.86	44.18	0	0	0
5	6.15	6.08	6.01	0	6.01
6	11.44	3.57	0	0	0
8	46.00	40.86	0	3.50	3.50
9	111.96	69.03	0	31.62	31.62
10	24.58	18.75	4.41	0	4.41
11	54.55	54.54	48.08	6.44	54.52
13	51.33	30.71	8.65	0	8.65
14	68.45	53.56	0	0	0
17	60.28	26.95	2.52	0	2.52
18	70.93	31.33	0	0	0
19	81.43	67.32	0.16	0	0.16
20	47.22	34.25	0.12	0	0.12
21	64.47	48.08	9.97	0	9.97
23	33.63	22.91	0	0	0
24	166.18	104.40	0	0	0
25	215.50	184.67	0	0	0
26	191.19	102.16	7.71	0	7.71
27	7.57	4.02	0	0	0
28	28.39	26.12	0	0	0
29	32.40	12.68	0	0	0
30	29.96	13.76	0	0	0
31	183.49	105.97	0	0.02	0.02
32	117.78	98.22	5.75	0	5.75
33	79.61	45.33	0	0	0
34	49.58	40.09	10.59	0	10.59
35	57.46	40.58	0	0	0
36	105.62	66.67	7.37	0	7.37
37	76.48	19.13	0	0	0
38	63.41	25.13	0	0	0
39	175.75	33.67	0	0	0
40	23.24	18.10	0	0	0
41	129.82	97.44	0	0	0
42	16.80	11.85	0	0	0
43	67.04	57.44	0	0	0
44	82.40	67.27	0	2.45	2.45
45	248.24	248.24	0	12.81	12.81

Table 13 - TIME REQUIRED FOR DATA ENTRY, MOSS GYPSY MOTH DATA BASE, MIFFLIN COUNTY, PENNSYLVANIA

Data Theme		Hours/Mi^2[1/]	Total Time (Hours)
Mifflin County Boundary	(CNT)	.05	20
Forested Areas	(FOR)	.23	96
Landownership Class	(OWN)	.05	20
Roads	(RDS)	.06	28
1981 Spray Blocks	(BLK)	.03	11
Major Streams	(STR)	.08	31
Towns	(TWN)	.02	9
1981 Defoliation	(DEF)	.13	55
1982 Defoliation	(D82)	.06	23
Total			293

[1/] Based on a MOSS generated estimate of 414.72 mi^2 in Mifflin County, Pennsylvania.

DISCUSSION

The Mifflin County gypsy moth data base demonstrates the ability of the Geographic Information System MOSS to effectively store, analyze and display spatial data of interest in forest pest management. Specific applications include reporting of the status of major pest outbreaks as mandated by the Cooperative Forestry Assistance Act (PL 95-313), development of a historical data base for reporting trends and assessing losses and planning and evaluation of suppression projects.

MOSS is capable of performing these tasks in a user friendly environment. An operator with no formal training in computer science can effectively execute system commands after approximately 20 hours of formal training in system operating procedures.

The availability of forest pest data stored in a GIS provides more opportunity to interface these data with other spatial data themes for pest impact assessment and provide for more timely reporting of data for pest management decision making.

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